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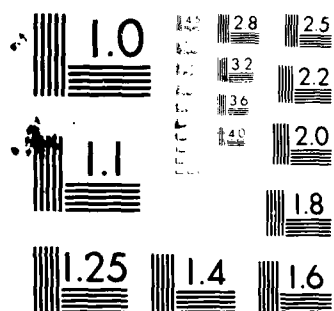
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DETERMINATION OF THE RELATIONSHIP BETWEEN
INFORMATION CAPACITY AND IDENTIFICATION BY
SIMULATED AERIAL PHOTOGRAPHY

by

Michael R. Jones

B.S. Rochester Institute of Technology

(1970)

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in the School of
Photographic Arts and Sciences in the
College of Graphic Arts and Photography
of the Rochester Institute of Technology

June, 1978

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 79-252T	2. GOVT ACCESSION NO. AD-A107485	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Determination of the Relationship Between Information Capacity and Identification by Simulated Aerial Photography.		5. TYPE OF REPORT & PERIOD COVERED THESIS/DISSERTATION
7. AUTHOR(s) Michael R. Jones		6. PERFORMING ORG. REPORT NUMBER
9. PERFORMING ORGANIZATION NAME AND ADDRESS AFIT STUDENT AT: Rochester Institute of Technology		8. CONTRACT OR GRANT NUMBER(s)
11. CONTROLLING OFFICE NAME AND ADDRESS AFIT/NR WPAFB OH 45433		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) (12) 47		12. REPORT DATE 27 June 1978
		13. NUMBER OF PAGES 37
		15. SECURITY CLASS. (of this report) UNCLASS
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES APPROVED FOR PUBLIC RELEASE: IAW AFR 190-17 FREDRIC C. LYNCH, Major, USAF Director of Public Affairs Air Force Institute of Technology (ATC) Wright-Patterson AFB, OH 45433		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) ATTACHED 81 3 63		

ACKNOWLEDGMENTS

This thesis is a result of the effort of many more people than just the author and it is appropriate to acknowledge some of them here. First I would like to thank my advisor, Professor Mohamed Abouelata, who gave me the initial idea for this paper. Without his inspiration and continued advice and counsel, this thesis would probably never have been completed. A special thanks must go to Lucy Nucelli who voluntarily typed and edited drafts, and to Mary Bender and Mary Byrne who typed the final manuscript. Finally, I wish to acknowledge my wife for her patience and constant support.

DETERMINATION OF THE RELATIONSHIP BETWEEN INFORMATION
CAPACITY AND IDENTIFICATION BY SIMULATED AERIAL PHOTOGRAPHS

by

Michael R. Jones

Submitted to the Photographic Science and Instrumentation Division in partial fulfillment of the requirements for the Master of Science degree at the Rochester Institute of Technology

ABSTRACT

➤ The relationship between information capacity and the ability of photointerpreters to identify vehicles in simulated aerial reconnaissance was investigated. An aerial scene lighting simulator was constructed and used in the production of a series of simulated aerial reconnaissance photographs of models of military tanks and trucks. The information capacity of these photos was varied by defocussing the taking camera and the simulated ground scale was varied by changing the taking camera reduction. Duplicate positives of these images were evaluated by trained military photointerpreters who determined the resolving power and attempted to identify the vehicles from a key provided. The resulting empirical probability of correct identification for each vehicle was plotted against the information capacity, which was computed as one half the square of the resolving power. For a probability of correct identification of 0.80, these curves indicate that an information capacity of 7.4 bits per square meter on the ground is required to identify tanks, and 2 bits per square meter is required for identification of trucks.

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I. INTRODUCTION

Image evaluation techniques have progressed a great deal since Foucault first used a target of light and dark lines to test lens quality in 1858¹. The smallest separation of details in the imagery has always been a natural evaluator, and resolving power as we know it has been in use in photographic systems since well before World War II. It is still one of the most common image evaluation techniques. Despite this almost constant use, resolving power has several detracting features, and many new techniques have been devised over the past few decades in an attempt to find a more accurate and precise measure of image quality. Techniques such as acutance, signal-to-noise ratio, granularity, modulation transfer function, and information theory have enjoyed differing amounts of acceptance and use. As each of these new techniques are developed, a continual challenge is to relate them to the imagery. Regardless of the ease of measurement and repeatability of any image evaluation technique, it is of little use if the correlation between the measure and the usefulness of the imagery, in its actual application, is not known.

¹ Reid, Charles D., Phot. Sci. Eng., 10, 5 pp 241-258 (1966).

The purpose of this experimental study was to investigate the relationship between information capacity (as defined by Riesenfeld²) and the usefulness of the imagery for photographic interpretation. I chose to investigate this relationship as it applies to aerial reconnaissance because my experience and interest are in this area, because of the continuing use of a single criterion (ground resolution) in judging the quality of reconnaissance systems, and because little is published relating laboratory estimates of image quality and subjective evaluation of the imagery. Riesenfeld's formula for information capacity was chosen because it is relatively new and can be related back to ground resolution, which is still extensively used to evaluate and compare aerial reconnaissance systems.

Several investigators have studied the relationship between resolving power and detection and recognition of geometrical objects. The classic experiment was that of MacDonald and Watson³; however, a very similar and more recent experiment conducted by Carman and Charman⁴ is more useful to discuss for our purposes, since they employed emulsions more representative of today's practice, and included resolving power targets of different types and contrasts.

²Riesenfeld, James, Phot. Sci. Eng., 11, 6 pp 415-418 (1967).

³MacDonald, D. E., and Watson, J., J. Opt. Soc. Am. 54, 9 pp 1121-1130 (1964).

⁴Carman, P.D., and Charman, W.N., J. Opt. Soc. Am. 54, 9 pp 1121 - 1130 (1964).

Their experimental setup was essentially the same as MacDonald and Watson's. Photographs were taken of three different resolving power targets and a target array of squares and circles that were used for detection and recognition, and two contrasts for resolving power. The scale of the photography and the lens aperture were varied to change the size of the targets on the film plane and the system modulation transfer function.

The detection and recognition targets consisted of squares and circles placed in a 4 by 4 matrix. The detection task, when examining the negative, was to correctly indicate the presence or absence of a target at each of the 16 positions. The recognition task was to correctly indicate the presence of either a square or a circle at each position. The probability of detection and recognition at each scale-aperture combination was determined from the results of at least four observers for each combination. This probability was plotted against the reciprocal of scale and the reciprocal scale corresponding to 75 percent probability was chosen as the threshold for detection or recognition of each combination of aperture, target type, and contrast, and emulsion.

Results were plotted as reciprocal diameter of the disc just recognizable or detectable at the threshold versus the resolving power as reported by each of the resolving power target types and contrasts. The most important conclusion derived from these plots (insofar as it applies to the experiment reported in this paper) was that the high contrast USAF tribar target gave the worst correspondence with

recognition and detection. This lack of correspondence was postulated to be because the "form and contrast" of the USAF high-contrast target was the most unlike the form and contrast of the recognition and detection target.

In a result similar to the above postulate, Riesenfeld found that "grain has a greater (adverse) effect on ability to resolve bars and identify letters than on ability to resolve squares."

Since the form of the squares and circles used by Carman and Charman is quite different from that of normal aerial reconnaissance targets, the above postulate leaves the applicability of their results in question. The experiment discussed in this paper is very similar to Carman and Charman's work; in that, the relationship between an objective image evaluation technique and subjective analysis is determined. The major differences are the simulation of the conditions of actual aerial reconnaissance and the use of realistic targets. These differences make the results of this experiment applicable to actual reconnaissance imagery; however, this advantage of realism and applicability is balanced by the variability resulting from the variety of parameters (such as target shapes, shadows, sun angle, etc.) affecting an interpreter's ability to identify the targets.

II. EXPERIMENTAL PROCEDURES

The basic aim of the experimental procedure was to simulate, as realistically as feasible, a military photographic reconnaissance mission. This was done by photographing models of military targets, processing and duplicating the resulting images, and requiring actual military photointerpreters to identify the models photographed and determine the system resolving power. The scale of the imagery was varied by changing the camera to scene distance and the system resolution was varied by defocussing the lens.

The complete experimental procedure was performed two times. The first experiment produced results that were primarily used to define a starting point for the second experiment. In the first experiment, the photographic reduction was not great enough to make the models unidentifiable; that is, all of the photointerpreters were able to identify all of the models even at the greatest reduction used. The second experiment used the same procedure as the first, except that a lower resolution film was used, along with an inherently lower resolution aperture and greater photographic reduction. Appendix D diagrams the basic physical set up used for both experiments.

SCENE SIMULATION OF AERIAL RECONNAISSANCE

Target

The simulated ground scene consisted of an RIT three bar medium contrast (5:1) resolving power target, three neutral density patches, and six areas on which scale models could be placed. The resolving

power target was placed in the center of the scene area, which was painted a neutral gray resulting in 58 percent reflectance. The scale models were painted a uniform neutral gray resulting in 21 percent reflectance. Under these conditions the resolving power target and vehicles approximate actual aerial reconnaissance situations.

Scene Illumination

Lighting for the scene consisted of three sources designed to simulate three types of illumination encountered in aerial photography: direct lighting from the sun, diffuse lighting from the sky, and backscatter from particles in the atmosphere.

Direct lighting from the sun was simulated by a Honeywell 202 electronic flash aimed directly at the scene. The electronic flash to scene distance was approximately fifteen times the flash reflector diameter to insure that the illumination from the source arrived at the scene essentially parallel, just as direct sunlight does. The simulated sun angle (defined as the angle between the ground scene plane and the incoming rays) was 70 degrees. This angle was arbitrarily chosen as representative of an actual aerial reconnaissance situation, and remains constant throughout the experiment.

Diffuse lighting from the sky was simulated by another electronic flash covered by a Wratten 80A filter to adjust the color temperature of the unit to approximately 15,000⁰K, which is roughly the color temperature of the sky⁵. Light from this flash was bounced off of crinkled aluminum foil to diffuse the light before it illuminated the

⁵Brock, G. C. et. al., Photographic Considerations for Aerospace, ITEC Corp., Lexington, Mass. 1965, pp7.

simulated ground scene. The aluminum foil was placed perpendicular to the simulated ground scene in all directions to simulate the complete hemisphere of the blue sky light.

Atmosphere reflecting and scattering which is added to the ground scene luminance when viewed from above was simulated by a fluorescent light placed behind the simulated ground scene. Illumination from this source was reflected into the taking camera via diffusers placed around the periphery of the simulated ground scene. Tone reproduction studies indicated that this simulated haze lighting reduced the object contrast by approximately twenty percent, which is roughly representative of medium to low altitude reconnaissance on a fairly clear day⁶. Of course the scene contrast reduction in actual aerial photography is the result of a combination of many variables such as atmospheric transmission, reflectance, scattering, optical filtering, solar altitude, luminance of the ground scene, and the spectral sensitivity of the acquisition emulsion. Because of this great number of variables it is impossible to characterize the representative situation.

Taking Camera

A 35 mm camera with a 50 mm lens was used to photograph the simulated ground scene. An initial test of the lens using Eastman Kodak High Contrast copy film indicated that this system was capable of a low contrast resolving power of 140 lines per millimeter at an aperture of f/5.6. To vary the system resolution, the camera was

⁶Brock, G. C. et. al., Ibid, pp. 15-19.

defocussed by moving it from the best visual focus position according to the formula discussed in Appendix A. Defocus was recorded as 0, 1, 2, or 3 λ , corresponding to the optical path difference for a diffraction limited lens of the same aperture.

Film Type and Exposure

Two types of original negative film were used. The original exposures in the first experiment were made on Kodak Plus - X film. In order to decrease the system resolution and thus make the vehicle harder to identify, the original negative film for the second experiment was changed to Kodak Tri - X.

Exposure was varied by neutral density filters chosen to result in optimum resolving power for each film. Neutral density patches in the scene indicated that these exposures also resulted in vehicle and background densities on the toe and straight line portion of the resulting sensitometric curve.

Processing and Duplication

Processing of both the original negative and the duplication film was accomplished in a Kodak Versamat processor using Versaflow chemistry. Film transport speeds were adjusted to simulate, as close as possible, sensitometric data typical of that produced by tactical reconnaissance units for similar films. Complete processing data is contained in Appendix B.

Original negatives were contact printed on Eastman Kodak Type 2430 fine grain aerial duplicating film. Exposures were made from a point

source while negative to duplicate material contact was assured by a weighted glass plate.

EXPERIMENTAL DESIGN

Table 1 summarizes the experimental design for both experiment number one and experiment number two. Photographs of the simulated ground scene were taken at each of the defocus and camera to object distances listed in the Table.

TABLE 1 - Experimental Design

EXPERIMENT No. 1

Film - Plus -X

Target Vehicles - 4 Tanks, 3 Trucks

DEFOCUS (OPD)	OBJECT TO CAMERA DISTANCE (METERS)				
0λ	1.829	2.743	3.658	4.572	5.486
$1/2\lambda$	1.745	2.562	3.349	4.107	4.840
1λ	1.673	2.420	3.120	3.782	4.412
$3/2\lambda$	1.613	2.304	2.942	3.536	4.097
2λ	1.560	2.206	2.795	3.340	3.850

EXPERIMENT No. 2

Film - Tri -X

Target Vehicles - 6 Tanks, 2 Trucks

DEFOCUS (OPD)	OBJECT TO CAMERA DISTANCE (METERS)				
0λ	3.658	5.486	7.315	8.534	10.363
1λ	3.613	5.386	7.315	8.297	10.020
2λ	3.570	5.293	6.979	8.084	9.718
3λ	3.529	5.206	6.832	7.890	9.449

The results of the first experiment dictated the changes implemented in the parameters of the second experiment. As discussed earlier, the original negative film was changed to Tri - X and the lens aperture increased to $f/1.4$ to decrease the system resolution. Two additional model tanks were added to the target array to decrease the probability of correct identification due to pure chance, and one model truck was removed because it was clearly distinguishable from the rest even at the lowest system resolution.

In order to make the vehicle identification task more realistic, and to decrease the possibility of identifying a vehicle by a process of elimination, the vehicle sequence in the target array and the number of vehicles of a particular type were changed for each exposure. Vehicle sequence was determined by a random number generator that allowed up to three vehicles of the same type to be used in a single array. Two exposures were made for each defocus - distance combination in order to have at least one image of each vehicle at each combination.

EVALUATION OF IMAGERY

The simulated reconnaissance imagery was evaluated by trained Air Force photointerpreters. This evaluation consisted of determining the resolving power and identifying the vehicle sequence in each photograph. A copy of the "Photointerpreters Instruction," which was given to each photointerpreter before they evaluated the imagery, is included in Appendix C.

The evaluation task was completed in Richards light tables equipped with zoom microscopes, which are standard Air Force equipment items. All photointerpreters were familiar with this equipment and were urged to adjust both viewing illumination and magnification as they wished. Photointerpreters used in the first experiment had an average of four years of experience, and those used in the second experiment had an average of three and one half years of experience.

Vehicles were identified by an arbitrary letter designation, not by manufacturer or standard military designation. Letters were assigned to close up photographs of the vehicles and a copy of this "key" was provided for each photointerpreter so that he could report the proper letter designator after matching the vehicle in the test imagery with a photograph in the key.

Before each photointerpreter began evaluating the simulated reconnaissance imagery, he was given a set of resolving power training photographs to evaluate. The purpose of these photographs was to provide the photointerpreter practice at identifying the vehicles and reading the resolving power target. The resolving power training photographs were also used to identify any misunderstandings about the evaluation procedures before beginning on the actual test imagery. The resolving power of each of the resolving power training photographs, as agreed upon by Professor Abouelata and this student, was used as the "aim resolving power." Photointerpreters independently determined the resolving power of each training photograph and then compared their answer to the "aim resolving power." Discrepancies of more than one

target element were discussed and reviewed until they were resolved.

After each photointerpreter had satisfactorily completed the resolving power training exercise, he began evaluating the test imagery. Photointerpreters worked independently and at their own pace, resting whenever they felt they needed to.

III. RESULTS AND DISCUSSION OF RESULTS

The results of the first experiment were of limited use since the photographic reduction was not great enough to make the models unidentifiable, as discussed previously. The results were used to define the parameters of the second experiment.

Both a "subjective" and an "objective" performance score - identification probability and information capacity respectively - was computed for each defocus-distance combination. Identification probability was computed as the number of correct identifications of a vehicle divided by the number of opportunities to identify that vehicle. Thus, identification probability was computed for each vehicle at each defocus-distance combination. Information capacity was computed as one half the square of the resolving power. Resolving power was computed by National Bureau of Standards methods.

The information capacity results from experiment two did not come out as expected and this required a departure from the planned method of analysis. The planned method of analysis was similar to that of Carman and Charman. Probability of correct identification for each vehicle was to be plotted against photographic scale at each defocus condition. The reciprocal scale required for an identification probability of 0.75 was to be taken from this plot, and this threshold scale for each model vehicle plotted against the information capacity resulting from the defocus condition. This plot would thus express the relationship between the threshold scale required for identification and system information capacity.

TABLE 2 - Image Plane Information Capacity (bits/mm²)

CAMERA TO OBJECT DISTANCE (AT 0λ)	DEFOCUS (λ)			
	0	1	2	3
12'	205	252	155	240
18'	369	356	344	332
24'	329	314	378	362
28'	320	425	254	-
34'	528	493	466	348

Table 2 displays the image plane information capacities obtained from experiment two for each defocus series. It is apparent that information capacity is not strickly defocus dependent through the range of camera to object distances used in this experiment. Because of this failure to obtain a correlation between defocus and information capacity, the planned method of analysis could not be used.

Even though the planned method of analysis could not be used, very cseful information can be obtained from the results of the second experiment when they are plotted as identification probability versus simulated ground information capacity. Plots of this type for each vehicle are included as Figure one through eight on pages 15 to 18. The information capacities and identification probabilities reported in these figures are taken from imagery with the highest reported object plane resolving power within each defocus series. For a complete table of this data for each defocus-distance combination, see the author's original paper. The circles identify data points from experiment two, and the X's identify data points from experiment one.

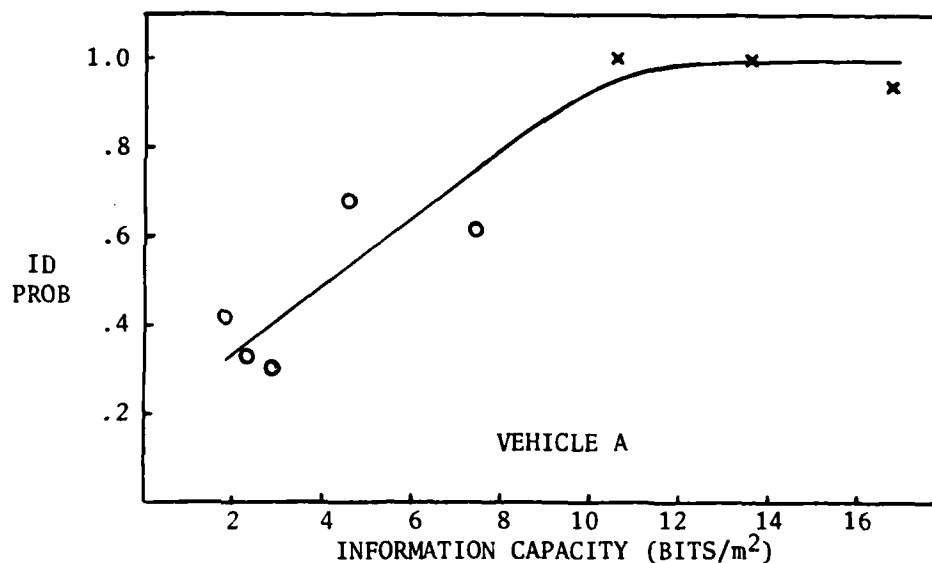


Figure 1. Probability of vehicle identification (ID PROB) Vs simulated ground information capacity - Vehicle A.

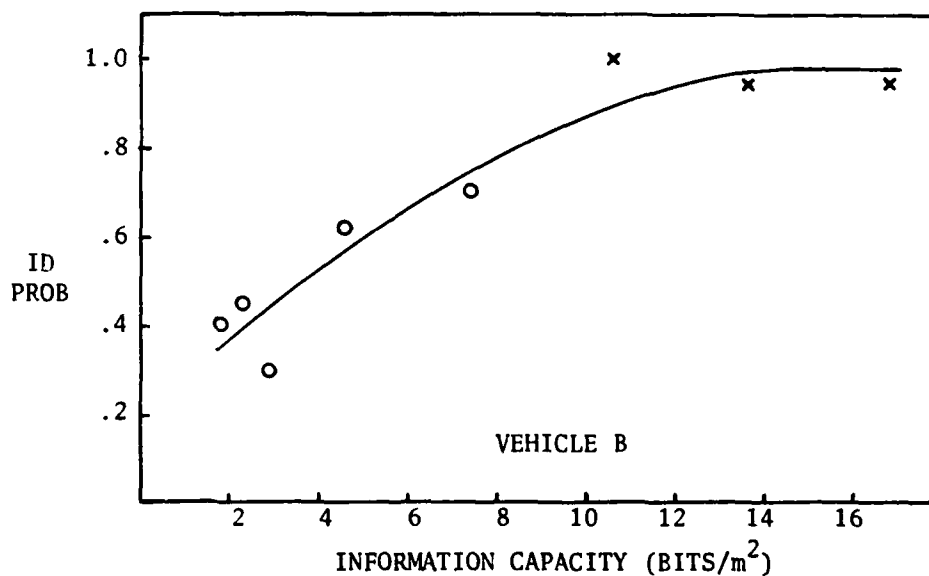


Figure 2. Probability of vehicle identification (ID PROB) Vs simulated ground information capacity - Vehicle B.

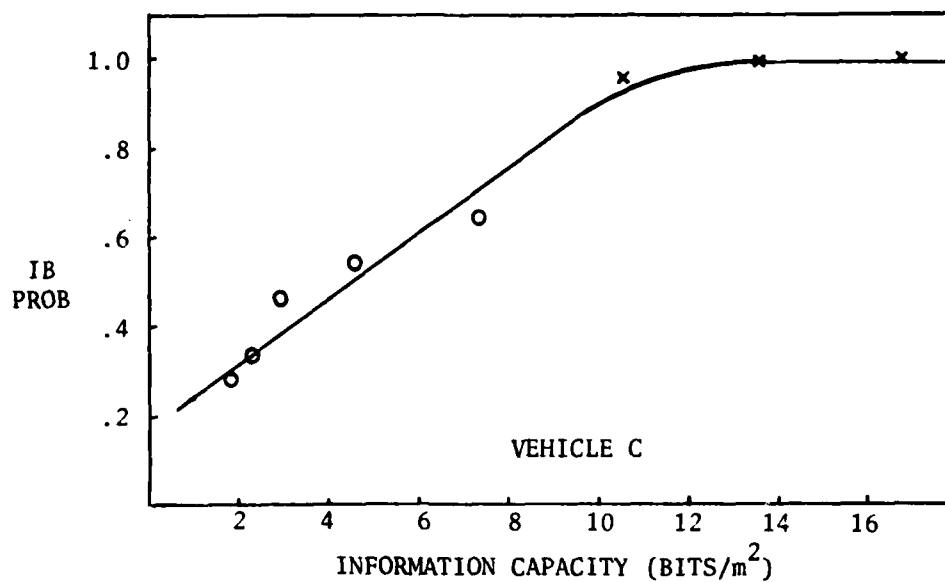


Figure 3. Probability of vehicle identification (ID PROB) Vs simulated ground information capacity - Vehicle C

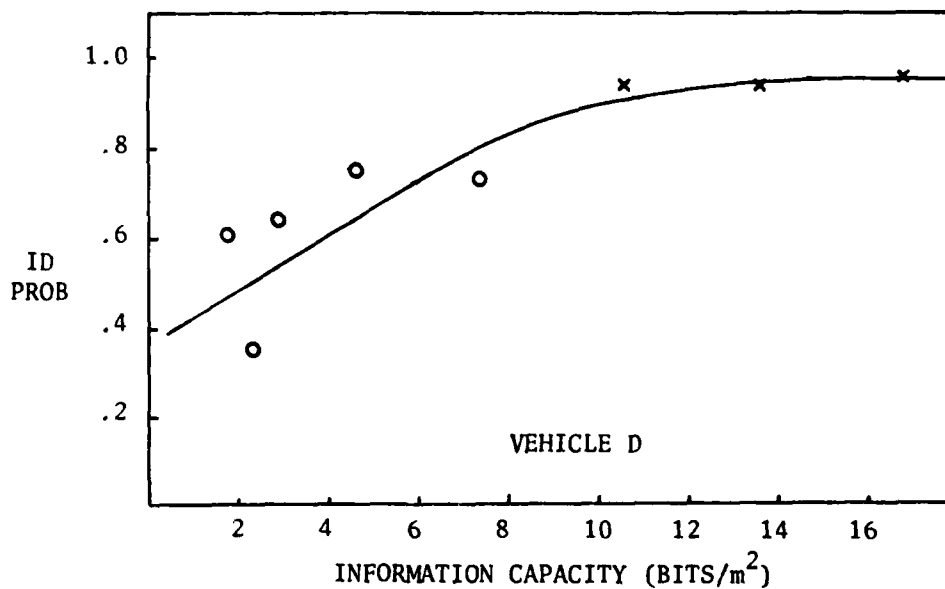


Figure 4. Probability of vehicle identification (ID PROB) Vs simulated ground information capacity - Vehicle D.

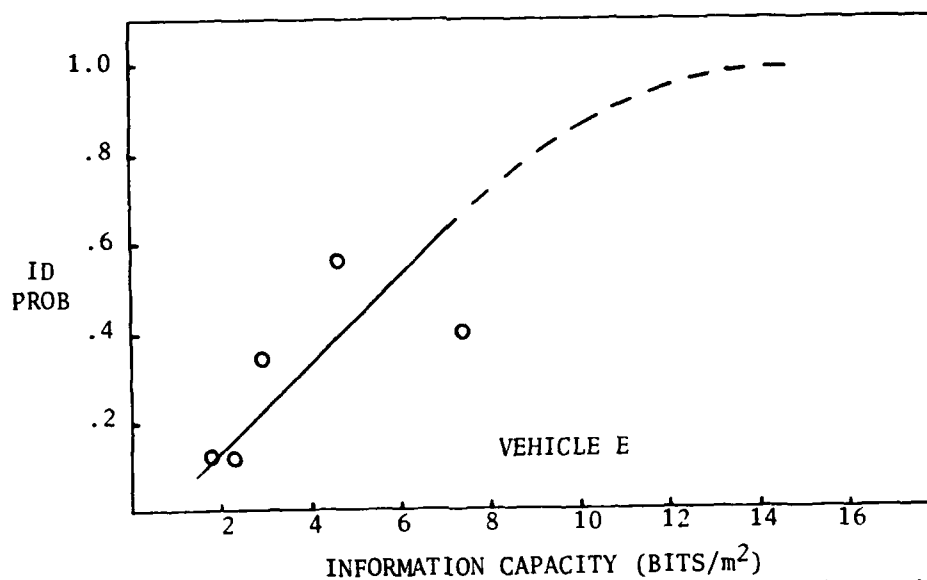


Figure 5. Probability of vehicle identification (ID PROB) Vs simulated ground information capacity - Vehicle E.

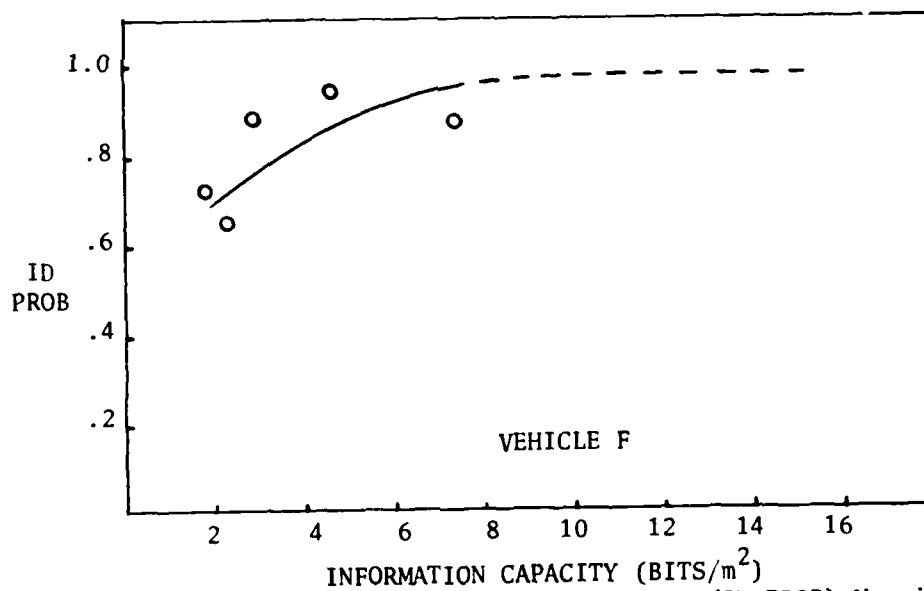


Figure 6. Probability of vehicle identification (ID PROB) Vs simulated ground information capacity - Vehicle F.

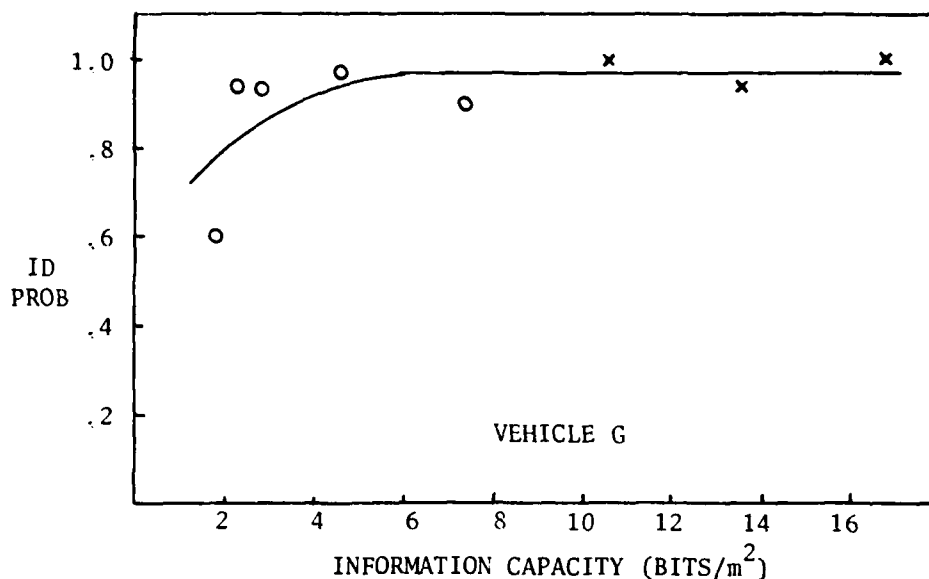


Figure 7. Probability of vehicle identification (ID PROB) Vs simulated ground information capacity - Vehicle G.

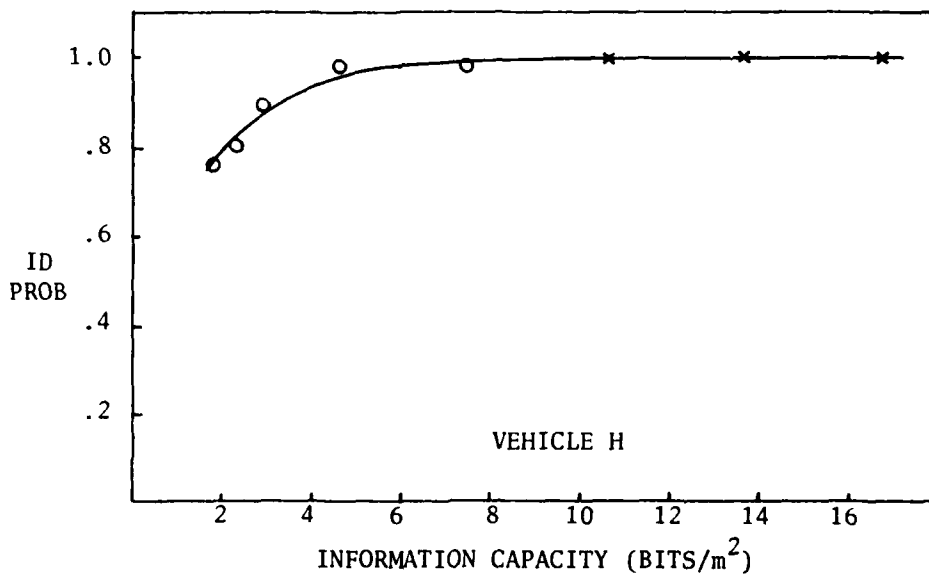


Figure 8. Probability of vehicle identification (ID PROB) Vs simulated ground information capacity - Vehicle H.

The solid line in each figure was determined from a visual fit of the experimental data and the following additional constraints as required by the physical situation. First, the value of the identification probability can be expected to approach unity at large information capacities; however, it can never exceed this value. This results from the definition of probability. Second, the value of the identification probability does not approach zero at very small information capacities, but approaches some small probability which is dependent upon the number of different responses possible. This is because at very small information capacities, where all vehicle are degraded so that there is no way to differentiate between them, the observer's responses must be based on pure chance. In this situation, if we assume independence between observers, the identification probability becomes a binominal distribution with the probability of each observer guessing the correct target equal to one over the total number of vehicles that could be guessed.

Upon questioning, experiment two observers indicated that they were in fact forced to rely on pure chance to identify the vehicles in some of the highly degraded imagery. All observers felt, however, (and their responses bare this out) that they could easily differentiate between the two classes of targets (trucks and tanks) even in the most severely degraded imagery. Since there were twenty observers and six tanks in experiment two, a binominal distribution assumed for the very low information capacity imagery of tanks results in a mean

probability of 0.15. Thus, we expect the theoretical plot of identification probability versus information capacity in Figures 1-6 to approach a probability of 0.15 at very small information capacities. Similarly, since there are only two vehicles in the truck class, the theoretical plot in Figures 7 and 8 should approach an identification probability of 0.5 at very low information capacity.

The above explanation of the binominal nature of the probability distribution at small information capacities is important in understanding the variability of the results. At low information capacity values where all six tanks have equal probability of being guessed, there is an approximately ten percent chance that the identification probability will be greater than 0.25, and an approximately 33% chance that it will be less than 0.10. At intermediate values of information capacities where two tanks can be eliminated and the remaining four tanks have equal probability of being guessed, there is an approximately 17% chance that the identification probability will be greater than 0.4, and an approximately 22% chance that it will be less than 0.15. Thus, the fit of the data points to the theoretical line is not as bad as might be expected, since a great deal of variability is inherent in the mathematics of the situation.

Figures one through eight can be used to determine the information capacity required to identify a vehicle at any specific confidence. An experiment by Frank Scott, Peter Hollanda, and Albert Harabedian⁷

⁷Scott, F., Hollanda, P. A., and Harabedian, A., Phot. Sci. Eng., 14 1 pp 21-27 (1970).

determined a similar relationship between identification accuracy and the number of scans per vehicle for noiseless, static, line-scan images. For tanks and trucks similar to those used in this experiment, they found that approximately twenty and eight lines per vehicle respectively were required for the subjects (college students) to identify them with 80 percent accuracy. Table 3 shows the corresponding data taken from figures one through eight. Note that one line per object is equivalent to two line-scans per object. The average number of lines per object in Table 3 is thus approximately 2.4 times that determined by Scott and his co-workers. This is not unreasonable given the difference in noise and contrast between the two experiments and tends to support the accuracy of the results.

TABLE 3. Number of lines per vehicle required for
80 percent identification probability

VEHICLE	A	B	C	D	E	F	G	H
LINE/VEHICLE	26	24	24	28	28	15	8.6	9.2

AVERAGE FOR TANKS - 24 LINES/VEHICLE

AVERAGE FOR TRUCKS - 8.9 LINES/VEHICLE

The results do not indicate that observer's experience or speed of identification are indicators of his identification accuracy.

IV. SUMMARY AND CONCLUSIONS

Vehicle identification was examined as a function of information capacity in simulated aerial photography. Two separate experiments were accomplished over two ranges of information capacity. The results of these two experiments complemented each other quite well as the two vehicle identification curves fit together to form a continuous curve. For 80 percent correct identification, an information capacity of 7.4 bits per square meter on the ground is required for identification of tanks, and 2 bits per square meter is required for identification of trucks.

These results can be used as a guide in determining what can be expected from an aerial reconnaissance mission in terms of photointerpreter's ability to identify vehicles. Whenever these results are used in this manner, the limitations of this experiment must be considered, however. Information capacity as used here does not completely define the system, especially as haze and altitude - and thus scene contrast varies. Application to situations that are considerably different from the simulated aerial reconnaissance situation will result in errors. Variations from the 70 degree sun angle used in this experiment will very likely affect the vehicle identification probability. A similar follow-on experiment could be designed to test this relationship. Part of a trained photointerpreter's method of identifying objects relies on the other related objects in

the scene, such as support equipment or vehicle tracks on the ground. This additional information was not available to the photointerpreters in this experiment. Even though these variables could not be considered in this experiment, an intuitive understanding of them will aid in the proper application of the experimental results.

APPENDICES

APPENDIX A
METHOD OF LENS DEFOCUS

METHOD OF LENS DEFOCUS

The aim of this method was to defocus the camera lens in relatively precise known amounts without the problems of precisely measuring film plane to principal plane shifts. The method first involved determining the best visual focus using a split image focusing mechanism. The film plane to principal plane distance defined by this best visual focus is then held constant throughout the defocus series. The camera is then moved toward the target an amount (δ) determined by the formula discussed below. This change in the principal plane to object distance results in a shift in the best visual focus position by an amount (δ') determined by the well known equation for optical path difference (OPD):

$$OPD = \frac{1}{2} \delta' \sin^2 \alpha'$$

Rearranging we have:

$$\delta' = \frac{2 OPD}{\sin^2 \alpha'}$$

From the definition of f/number (N):

$$\delta' = 8 OPD N^2 \quad (1)$$

Using equation one we can determine the shift from best focus corresponding to any specific optical path difference. This difference is very small and would thus be difficult to measure accurately as mentioned above. This problem can be eliminated by using equation

two below to determine the amount the principle plane to object plane must be changed to get this focus shift.

$$\delta = \frac{1}{M^2} \delta' \quad (2)$$

Where M is the lateral magnification of the system.

Since both δ and M are variables, equation two must be solved by an iterative process. The solution gives the distance the camera must be moved from its original best visual focus position to give an image out of focus by the optical path difference input into equation one.

These equations are accurate only for a diffraction limited lens. The lens used in experiment two obviously was not diffraction limited at the aperture used ($f/1.4$). This aperture had to be used, however, in order to obtain the proper range of identification probabilities as explained in Section II. The errors introduced by the lens aberrations should have little effect on the utility of the method since they are consistent for each defocus condition.

APPENDIX B
ORIGINAL NEGATIVE AND DUPE PROCESSING DATA SHEETS

DENSITY VS LOG EXPOSURE

PLUS X FILM PROCESSED IN RIT VERSAMAT WITH VERSAFLOW CHEMISTRY.
PROCESSING SPEED - TWO FEET PER MINUTE.

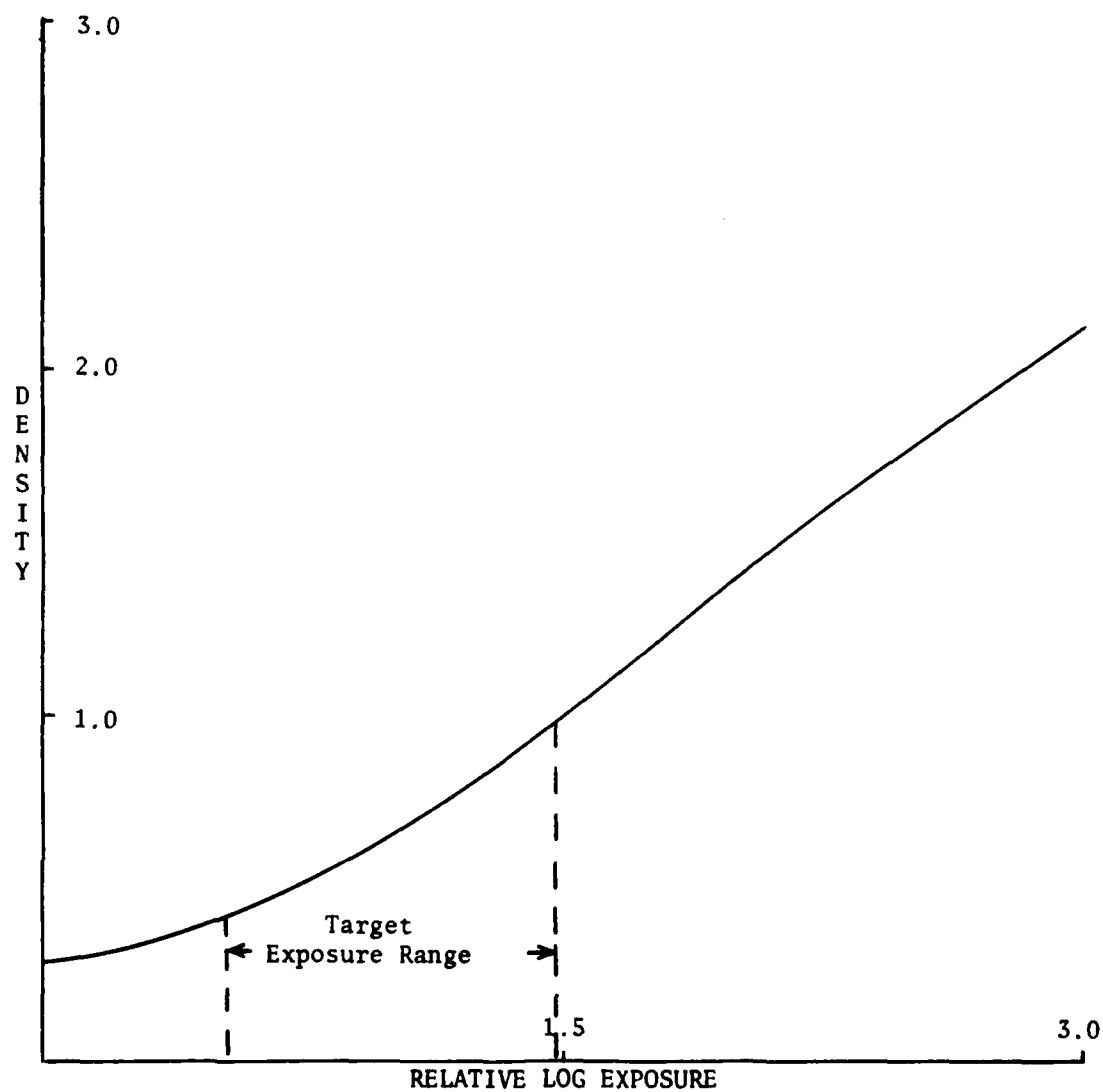


Figure 9. Original Negative Characteristic Curve - Plus - X.

DENSITY VS LOG EXPOSURE

TRI X FILM PROCESSED IN RIT VERSMAT WITH VERSAFLOW CHEMISTRY.
PROCESSING SPEED - TWO FEET PER MINUTE.

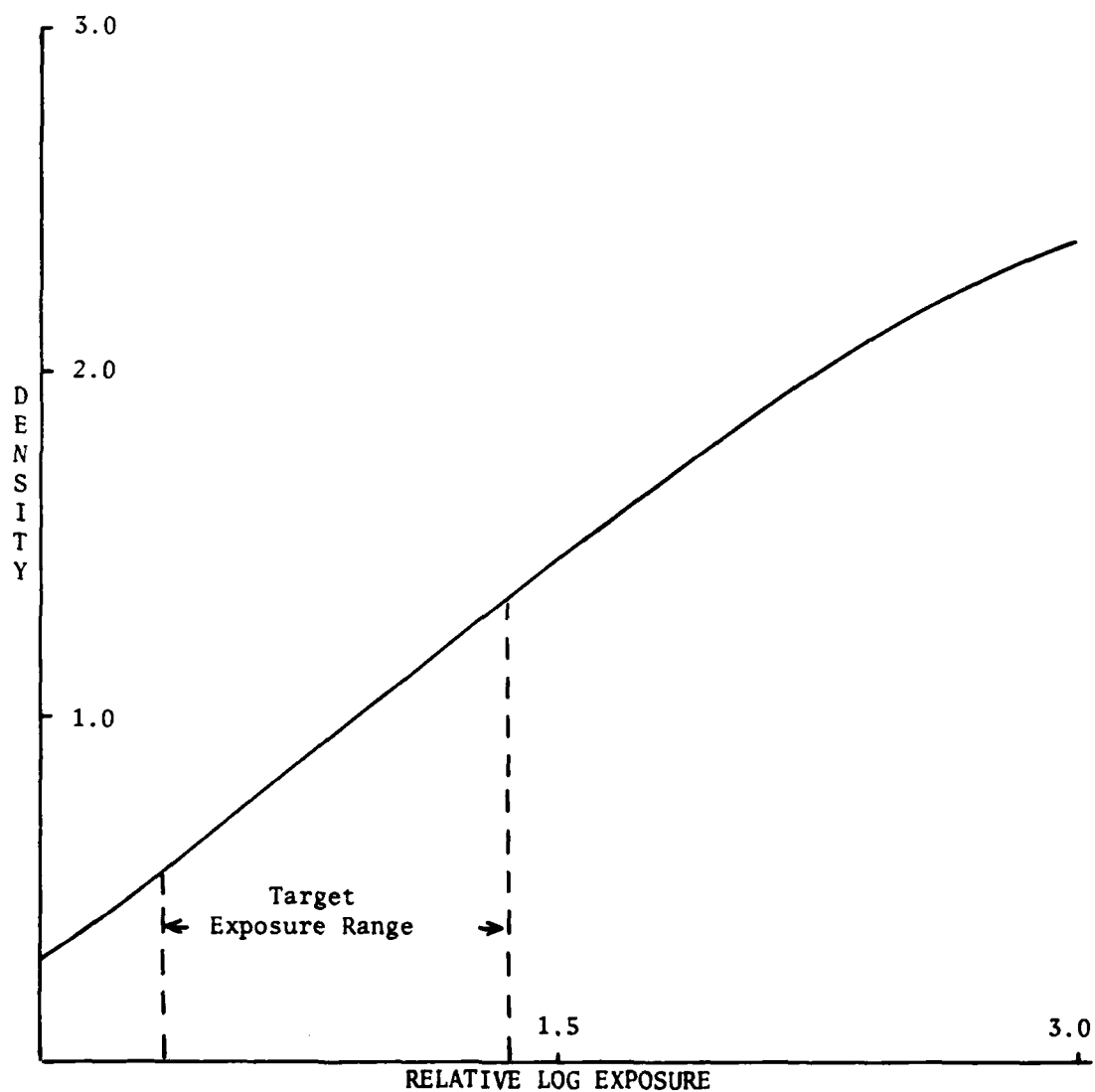


Figure 10. Original Negative Characteristic Curve - Tri - X.

DENSITY VS LOG EXPOSURE

FINE GRAIN AERIAL DUPLICATING FILM, TYPE 2430, PROCESSED IN RIT
VERSAMAT WITH VERSAFLOW CHEMISTRY.
PROCESSING SPEED - 4 FEET PER MINUTE

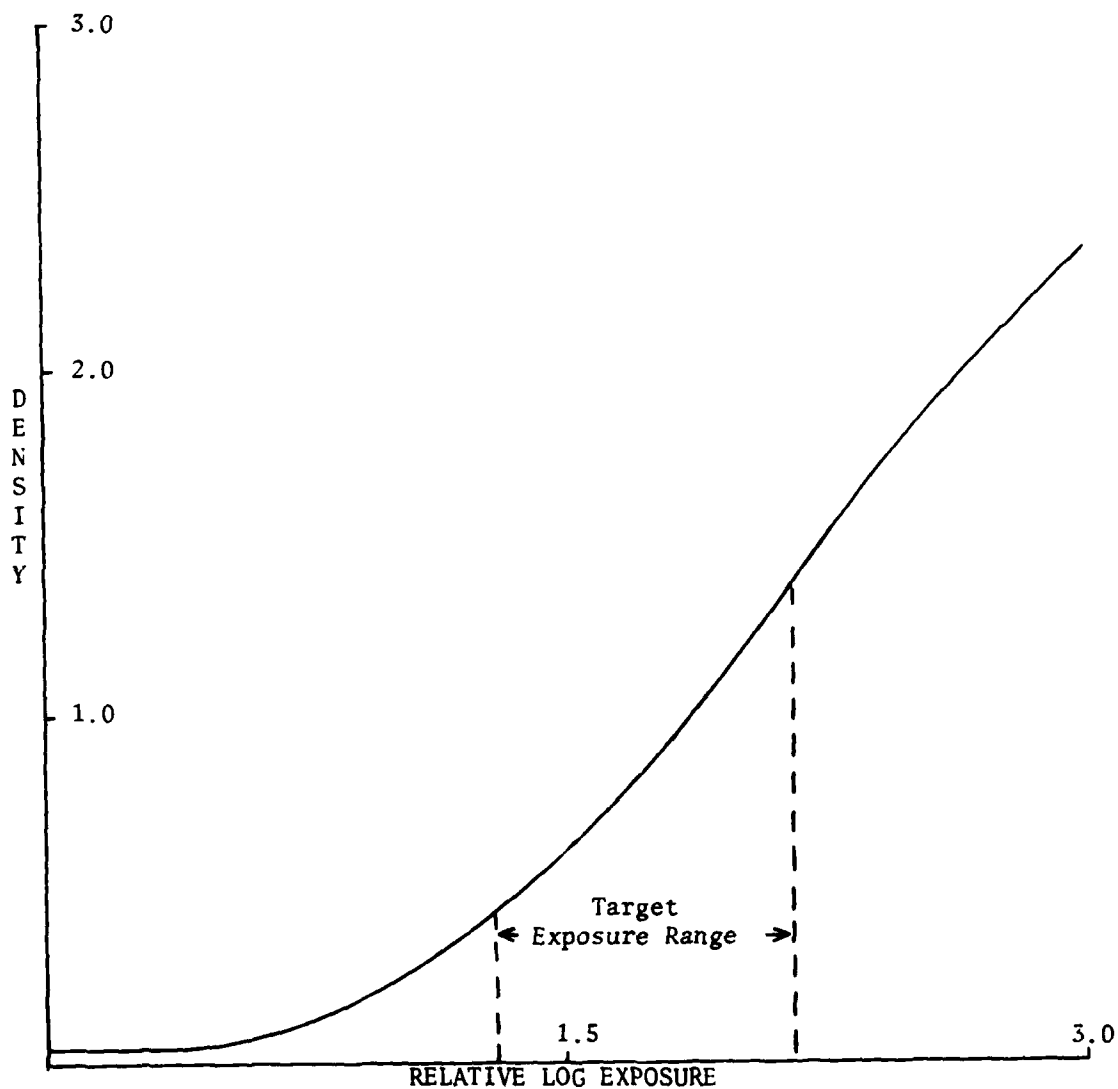


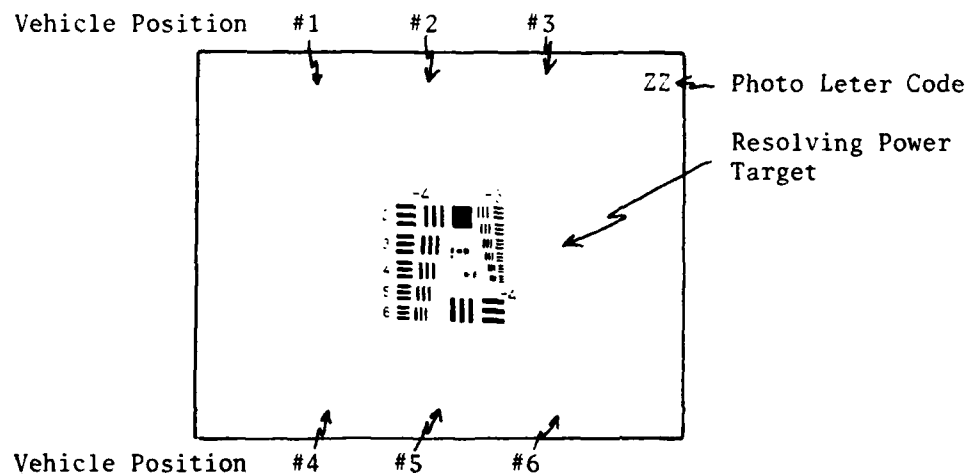
Figure 11. Duplicate Characteristic Curve - Type 2430.

APPENDIX C
INTERPRETERS INSTRUCTIONS

INTERPRETERS INSTRUCTIONS

This project is an attempt to relate some aspects of the quality of photographic images with the ability of trained photointerpreters to identify targets in the photographs. I have made photographs of a variety of military vehicles and have introduced certain degradations into the photographs. Now I want to see how those degradations effect your ability to identify the vehicles.

Each photograph consists of two horizontal rows of three target vehicles above and below a resolving power target, as shown below.



Your task is to identify the vehicles and read the resolving power target in each photograph. The following paragraphs explain how you are to do this. Please follow the instructions as closely as you can - it is imperative that everyone follows the same procedures.

Before viewing any photographs, make sure the photograph letter code is in the upper right corner of the slide mount.

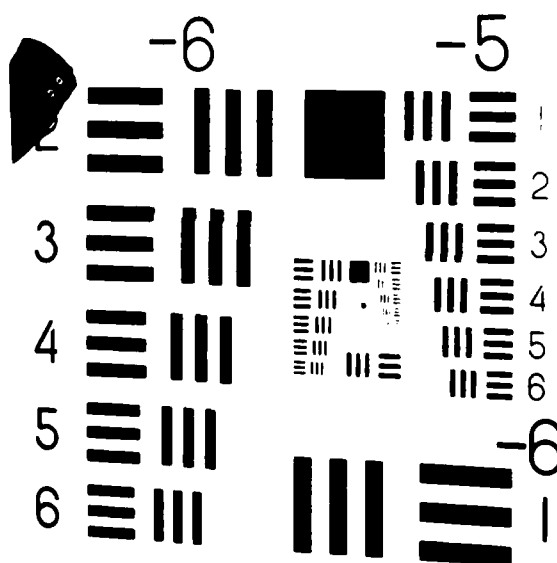
1. Identifying vehicles. Do not try to identify the vehicles by their military designation, manufacturer, or country of origin. Find the vehicle in the identification key provided and record the identifying letter only. Vehicles of the same type and manufacturer (i.e. AMX-30 tanks) are not identical -- some minor differences may be noticeable, such as an externally mounted machine gun may or may not be in place, or a turret hatch may be open or closed.

Each photograph contains six vehicles, however, these vehicles could be all the same type or all different. Do not try to guess the identity of a vehicle by assuming any kind of sequential or orderly placement of the vehicles in the photograph - the vehicles were placed in each photograph in random order.

Use whatever magnification you feel comfortable with to properly identify the vehicles. When you have identified a vehicle with its identifying letter, make sure of the vehicle position number and record the identifying letter under that vehicle position on the tally sheet. After you have become familiar with the vehicles you should take no longer than 15 seconds to identify each one. Don't spend a long time trying to identify one vehicle. If you're not sure, guess. Do not leave any blanks under vehicle position.

View the photographs in the order given (AA, AB, AC, ...) and only view one at a time to avoid confusion.

2. Reading the resolving power target. Use a microscope with at least 25X magnification to read the resolving power target. The resolving power target is in the center of each frame and consists of sets of bars of decreasing size as shown below. An element of the resolving power target consists of six bars of the same size -- three bars horizontal and three bars vertical. A set of six elements makes up a group. Each group is identified by a negative number (-6, -5, -4, ...) and each element within a group is identified by a positive number (1, 2, 3, 4, 5, or 6).



Resolving Power Target

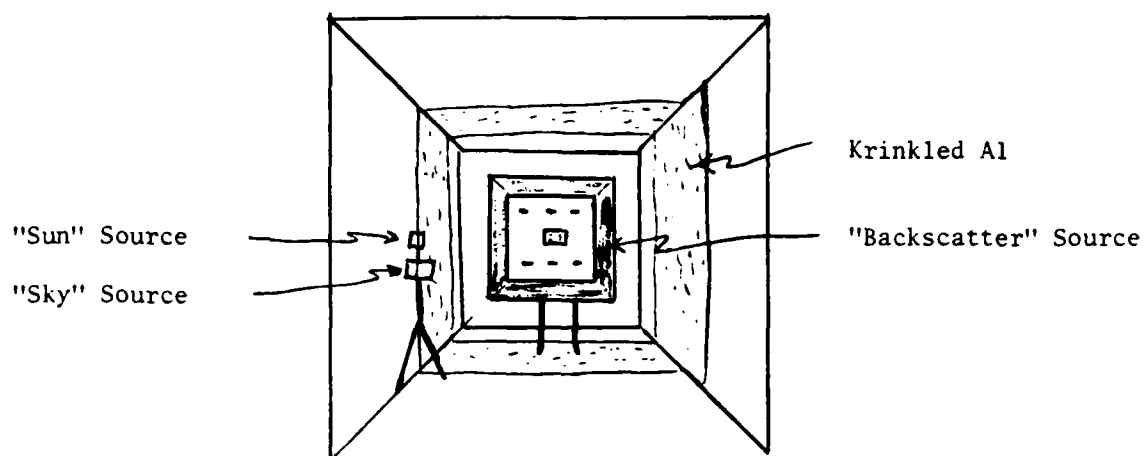
To read the target, simply determine the smallest element that is resolved and record that group and element number on your tally sheet.

A target element is considered resolved if the correct number of bar units (3), in both the vertical and horizontal direction, can be

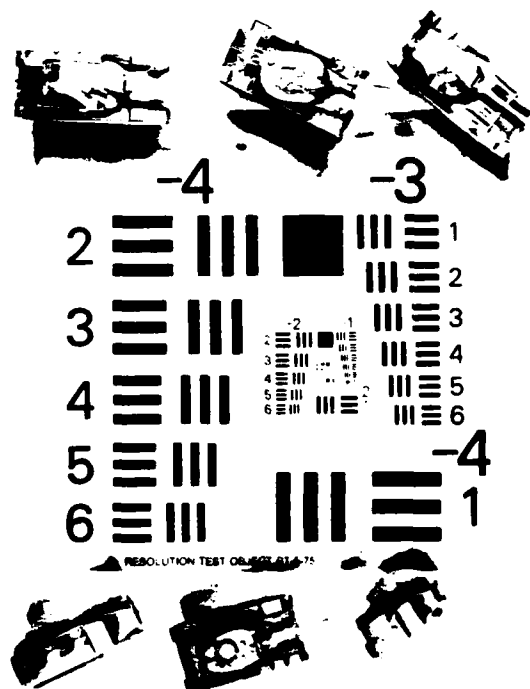
distinguished. No element shall be considered resolved unless all larger elements are resolved. Do not spend over ten seconds to determine which target elements are resolved. First impressions are usually best.

Enter the resulting numbers in the column headed resolving power beside the two letter code for that photograph. If no target elements are resolved, enter 0.

APPENDIX D
PHYSICAL SET UP



A. View of Apparatus from Taking Camera



B. Close up of Target and Vehicles

Figure 12. Physical Set Up

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